Green Manufacturing: Case Study using AHP and Grey Relation

Abhishek Kumar Singh, Shubhanshu Shekhar Shukla, Jaideep Dutta

***Abstract*— Green manufacturing is cooperative manufacturing based on various hierarchy resources. It's important to get the optimum Cooperative enterprise scheme by analyzing, arranging and evaluating the manufacturing capabilities of Industries for Green manufacturing. The paper analyzes correlation between five industries in the context of green manufacturing, with the help of relation matrix which is based on grey relation theory and AHP method. The paper analyses the environmental actions according to Green product design, Green design of raw material, Green process, Green Technology, Green packaging Material and Green Packaging design.**

***Index Terms*— AHP, Green Manufacturing, Grey Relation.**

I. INTRODUCTION

Based on different published literature, there are a lot of models proposed by different authors for selecting best methods to adopt green manufacturing practices on the basis of Analytical Hierarchy Process (AHP) [1]. This paper studies theory and method of green manufacturing practices followed in different industries namely Brick, Brassware, Carpet, Pottery and Match Box industries on the basis of grey theory and establish a relationship between them to observe their authenticity and effectiveness as shown in Fig (1).

The different variables taken in to considerations are [2]

a) Green Product Design (F1) which includes Eco-impact during product life cycle (V10) and compatibility with living environment (V12).

(b) Green Design Of Raw Materials (F2) comprises of ease of acquisition (V08), ease of replacement (V11) and ease of simplification (V13).

(c) Green Process (F3) is constituted of processes to reduce wastes (V01) and process to recycle materials (V05) and process to use re-manufacturing (V06).

(d) Green Technology (F4) includes environmental improvement of production (V02), technical innovation capabilities (V03) and comprehensiveness of eco standard test reports (V04).

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(e) Green Packaging Material (F5) includes application of eco-materials for packaging (V09) and recovery rate of packaging material (V15).

(f) Green Packaging Design (F6) comprises of reusable packaging (V07) and integration of eco marks into packaging design (V14).

II. GREY RELATION PRINCIPLE

Grey relation analysis belongs to grey system theory put forward by Professor Deng Ju-long in 1982, and it mainly researches quantification analysis problem of system state development. In grey relation theory [3], the geometry curve constructed by several stat. data is more similar, the relation degree is bigger. As Fig.2, the similarity degree of curve one and two is greater than similarity degree of curve one and three, and the relation degree of curve one and two is more than curve of one and three. The relation sequence reflects approximate sequence of each project to objective project, and the project of maximal grey relation degree is best one. For standard reference sequence x0=[x01, x02, …, x0n], xi=[xi1, xi2,…, xin] (i=1,2,…,m) is regarded as compared sequence, and the grey relation coefficient matrix is defined as following:

$$\xi_i^{(k)} = \frac{\Delta max + \sigma \Delta max}{\Delta ik + \sigma \Delta max} \quad (1)$$

$$\Delta min = min_i min_k |x_{ik} - x_{0k}| \quad (2)$$

$$\Delta max = max_i max_k |x_{ik} - x_{ok}| \quad (3)$$

$$\Delta ik = |x_{ik} - x_{ok}| (i = 1,2,\dots,m; k = 1,2,\dots,n) \quad (4)$$

σ is distinguishing coefficient, and it shows importance degree of unity in relation space. According to grey relation literature research, grey relation coefficient $\xi_i^{(k)}$ is monotone increasing function, and its principle is shown as following. The comparison mean of relation space is defined as $\overline{\Delta}$,

$$\overline{\Delta} = \sum_{i=1}^{m} \sum_{k=1}^{n} |x_{0k} - x_{ik}| / (n.m) \quad (5)$$

The scale coefficient of mean is $\gamma = \overline{\Delta} / \Delta max$.

(1) If $\Delta max > 3\,\Delta$, *then* $\sigma = (\gamma + 0.5)/2$ (When there is abnormal value in comparing set, Δmax is very big. Parameter σ hence should be taken smaller value to weaken influence of Δmax).

(2) If Δmax $< 3\Delta$ *then* $\sigma = (2\gamma + 0.5)/2$ (When comparing set is stable, Δ max is small. Parameter σ hence should be taken bigger value to increase relation degree unity).

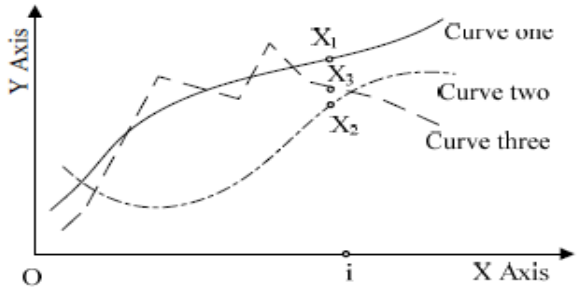

Fig 2: The thought of Grey Relation

III. THE INSTANCE OF INDUSTRY SELECTION FOR GREEN MANUFACTURING

For the process of industry selection is based on grey relation theory, we have to first create the standard reference set. For this, we selected five small scale industries i.e. brick, brassware, carpet, pottery and match box. These five industries were selected from an exhaustive list of small scale industries, based on the criteria that the process of green manufacturing can be utilized to a great extent in these five cases. The selected industries were graded according to the factors i.e. F_1, F_2, etc. The industries were ranked in a scale of 10 on the basis of their performances in these factors and thus a matrix was created as shown in Table 1. This matrix was validated by AHP method.

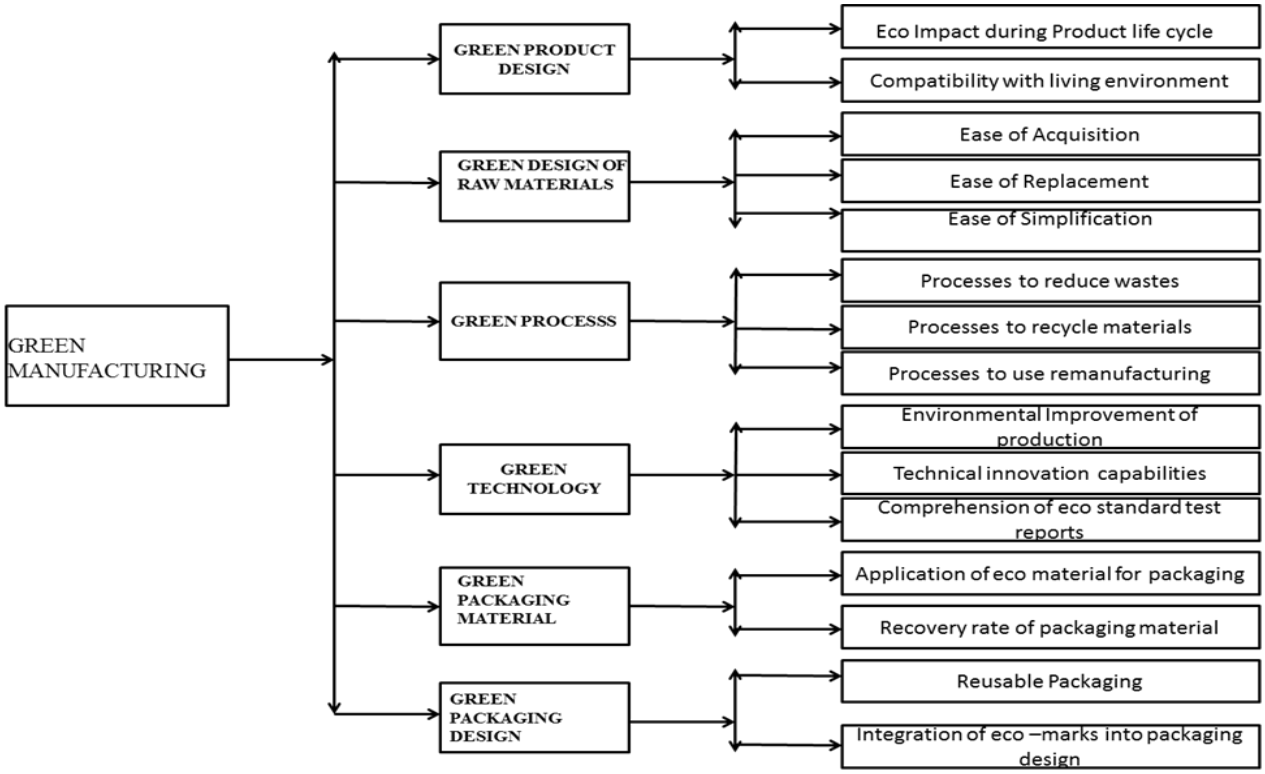

Fig: 1 Industry selection Evaluation Index System

Table 1: Detailed Information on Industries Inspected for Green Manufacturing

Industry	V10	V12	V8	V11	V13	V01	V05	V06	V02	V03	V04	V09	V15	V7	V14
Brick (I1)	5	8	7	2	7	4	8	7	2	2	2	3	2	2	3
Brassware, (I2)	7	2	3	5	4	5	2	7	3	5	4	4	5	7	4
Carpet (I3)	3	6	5	5	4	5	3	7	5	6	7	8	8	4	2
Pottery (I4)	7	7	7	5	8	7	8	8	7	6	5	6	5	5	7
Match Box (I5)	5	1	6	2	7	3	6	2	7	5	6	5	6	7	6

IV. THE AHP METHOD

AHP [4,5] is a systematic procedure for representing the elements of any problem hierarchically. The pair wise comparison matrix is of size n×n, where n is the number of elements to be compared pair wise as shown in Table 2. The matrix will be filled up accordingly using following procedures:

(a) Each element compared with itself will get a value 1 i.e. a(1,1)=a(2,2)=…a(n,n)=1.

(b) When ith element is compared with jth element , it has got a value A(I,j) , jth element being compared with ith element has got a value a(I,j)=1/a(1,2), a(3,1) = 1/a(1,3)…….a(n,1)= 1/a(1,n)

(c) Relative Weight (RW) = a(1,1)×a(2,1)×a(3,1)×a(4,1)×a(5,1)nn

(d) Normalized Weight (NW) = RW/Σ RW

(e) Maximum Eigen Value ($\lambda\lambda\lambda\lambda\lambda\lambda\lambda\lambda$) = Σcolumn A × NW value row A + = Σcolumn B × NW value row B + ……. + = Σcolumn n × NW value row n

(f) Consistency Index (CI) = ($\lambda\lambda\lambda\lambda\lambda\lambda\lambda\lambda$ - n)/ (n-1)

(g) Random Index (RI) = 1.98 × (n-2) / n

(h) Consistency Ratio (CR) = CI/ CR ,should be within 10 percent

(i) Composite rank (COR) = NW Parameter 1 weightage × NW of that Parameter + NW Parameter 2 weightage × NW of that Parameter +……. + NW Parameter n weightage × NW of that Parameter**.**

Table 2: The AHP matrix

1	1	3	2	3	2
1	1	2	3	3	4
1/3	1/2	1	2	4	3
1/2	1/3	1/2	1	3	2
1/3	1/3	1/4	1/3	1	3
½	1/4	1/3	1/2	1/3	1

Consistency check = 9%

V. CALCULATIONS

For establishing the grey relation theory, we must first pre treat the standard reference set according to the evaluation goal. The evaluation indexes can be divided into two types:

1) The smaller the value is the better it will be. The formula for this case is as follows: $\overline{\delta_{ij}} = [\delta_{ij}(\sum_{k=1}^{m} \delta_{kj}^{-1})]$ (6)

2) The bigger the value is better it will be. The formula for this case is as follows: $\overline{\delta_{ij}} = \delta_{ij} / (\sum_{k=1}^{n} \delta_{kj})$ (7)

From the above two formulas we deduced the first grade difference matrix shown in Table 3 i.e.:

Table 3: First Grade Difference matrix

0.074,0 :	0,0.157,0.033 :	0.125,0,0.032 :	0.20,0.16,0.20 :	0.19,0.23	:0.2,0.1818
0,0.25 :	0.142,0,0.133 :	0.08,0.22,0.032:	0.16,0.04,0.12 :	0.152,0.115	:0,0.136
0.1481,0.083 :	0.0714,0,0.133 :	0.08,0.18,0.03 :	0.08,0,0 :	0,0	:0.12,0.227
0,0.0416 :	0,0,0 :	0,0,0 :	0,0,0.083	0.076,0.115	:0.08,0
0.074,0.291 :	0.03,0.15,0.03 :	0.12,0.07,0.19 :	0,0.04,0.04 :	0.115,0.076	:0,0.045

According to definition of relation space comparison mean, $\overline{\Delta_1} = 0.09631, \overline{\Delta_2} = 0.05986, \overline{\Delta_3} = 0.07904, \overline{\Delta_4} = 0.07757, \overline{\Delta_5} = 0.10748, \overline{\Delta_6} = 0.09948$

In terms of equation (2) and (3), the maximum and minimum value of each first grade evaluation index respectively is:

$\Delta min_1 = \Delta min_2 = \Delta min_3 = \Delta min_4 = \Delta min_5 = \Delta min_6 = 0;$

$\Delta max_1 = 0.29166; \Delta max_2 = 0.150; \Delta max_3$ 0.22;

$\Delta max_4 = 0.208; \Delta max_5$ =0.23;$\Delta max_6 = 0.23$

The scale coefficient of mean is $\overline{\Delta_1} = \Delta / \Delta max$, thus, γ_1=0.33; γ_2 0.3788; $\gamma_3 = 0.3592; \gamma_4 =$ 0.372; γ_5 =0.4673;γ_6 =0.43252

The Distinguishing coefficients are:

$\sigma_1 = 0.4151; \sigma_2 = 0.6288; \sigma_3 = 0$ .6092;

$\sigma_4 = 0.62234; \sigma_5$ =0.7173;σ_6 =0.68252

First grade relation matrix can be obtained by equation (1) is shown in Table 4:

Table 4: First Grade Relation Matrix H= (H1, H2, H3, H4, H5, H6}

0.62,1.0 :	1.0,0.38,0.75 :	0.51,1,0.80 :	0.38,0.44,0.38 :	0.46,0.42	: 0.44,0.46
1.0,0.32 :	0.41,1.0,0.42 :	0.61,0.37,0.80 :	0.44,0.76,0.51 :	0.52,0.60	: 1.0,0.53
0.44,0.59 :	0.58,1.0,0.42 :	0.61,0.42,0.80 :	0.61,1.0,1.0 :	1.0,1.0	: 0.56,0.40
1.0,0.74 :	1.0,1.0,1.0 :	1.0,1.0,1.0 :	1.0,1.0,0.61	0.68,0.60	: 0.66,1.0
0.62,0.29 :	0.73,0.75,0.75 :	0.51,0.64,0.40 :	1.0,0.76,0.76 :	0.6,0.68	: 1,0.77

VI.CONCLUSION

With the help of relation matrix ,we established a correlation between various industries in the context of green manufacturing .Also by Using AHP ,we can find the weightage of a particular industry in green manufacturing considering the various factors associated with it. The future prospect of this work is finding the ranking of the industries considered with respect to green manufacturing .This will be obtained by further correlations .Hence in the process finding out the grey relation grade which would point out as which industry is the best among the selected in the context of green manufacturing.

VII.REFRENCES

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